

WHAT IS CLAIMED IS:

1. A control circuit for controlling a switching power converter, wherein said switching power converter includes a
5 power magnetic element having at least one power winding, a second winding, a switching circuit for periodically energizing said at least one power winding, wherein said control circuit controls said switching circuit, and wherein said control circuit comprises:

- 10 an integrator having an input coupled to said second winding for providing an output representing an amount of magnetic energy storage in said power magnetic element;
 a comparison circuit for detecting when said output of said integrator indicates that said amount of magnetic energy storage
15 has reached a level substantially equal to zero;
 a sampling circuit having a signal input coupled to said second winding and a control input coupled to an output of said comparison circuit for sampling a voltage of said second winding in conformity with said integrator indicating that said amount
20 of magnetic energy storage has reached said substantially zero level; and
 a switch control circuit having an output coupled to said switching circuit and having an input coupled to an output of said sampling circuit, whereby said switching circuit is
25 controlled in conformity with said sampled voltage.

2. The control circuit of Claim 1, further comprising:

a first detection circuit having an input coupled to said second winding for detecting a zero magnetic energy storage cycle point of a post-conduction resonance condition of said power magnetic element;

a hold circuit having an input coupled to said output of said integrator and a control input coupled to an output of said first detection circuit for holding a value of said output of said integrator at said zero magnetic energy storage cycle point;

a second detection circuit having a first input coupled to an output of said hold circuit and a second input coupled to said output of said integrator for detecting a beginning of a subsequent post-conduction resonance condition of said power magnetic element in conformity with said output of said integrator and said held value of said output of said integrator, and wherein said control input of said sampling circuit is coupled to said output of said second detection circuit, whereby said voltage of said second winding is sampled at a time preceding or equal to said beginning of said subsequent post-conduction resonance condition.

3. The control circuit of Claim 2, wherein said first detection circuit comprises:

a differentiator for providing an output corresponding to a derivative of said voltage of said second winding; and
a comparator for determining a time at which said derivative is substantially equal to zero, corresponding to said
5 zero magnetic energy storage cycle point.

4. The control circuit of Claim 3, wherein said comparator is biased with an offset voltage and includes hysteresis, whereby false tripping of said differentiator is prevented.

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5. The control circuit of Claim 4, wherein said output of said comparator is coupled to said hold circuit by a blanking circuit for enabling sampling of said integrator output only during post-conduction resonance intervals.

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6. The control circuit of Claim 2, wherein an output of said first detection circuit is coupled to said control circuit for activating said switching circuit at said zero magnetic energy storage cycle point, whereby efficiency of said power converter
20 is improved.

7. The control circuit of Claim 1, wherein said second winding is an auxiliary sense winding.

8. The control circuit of Claim 1, wherein said integrator further comprises a reset input, and wherein said reset input is periodically activated to remove accumulated integrator error.

5 9. The control circuit of Claim 1, wherein said integrator output is further coupled to said switch control circuit for deactivating said switching circuit when a level of magnetization current is reached in said power magnetic element corresponding to a difference between a voltage of said second 10 winding and a reference voltage, whereby a peak current of said switching circuit is regulated.

10. The control circuit of Claim 1, wherein said power magnetic element is further coupled to a load via at least one output 15 rectifier diode and wherein said comparison circuit is biased by an offset voltage, whereby said comparison circuit detects a point offset from when said output of said integrator indicates that said amount of magnetic energy storage has reached a level equal to zero, whereby said sampling circuit samples a voltage 20 of said second winding while said output rectifier diode is conducting a current determined in proportion with said offset voltage.

11. The control circuit of Claim 1, wherein said sampling circuit further comprises a compensation circuit for adjusting an output of said sampling circuit to provide an increase in said output of said sampling circuit, whereby an effect of
5 series resistance in a capacitor connected across an output of said power converter on an output voltage of said power converter is reduced.

12. The control circuit of Claim 11, wherein said sampling circuit comprises a hold circuit having an input coupled to said second winding and an output coupled to an error amplifier for comparing a held voltage of said second winding to a reference voltage, and wherein said compensation circuit comprises a resistor coupled between an input of said hold circuit and an
15 output of said error amplifier.

13. The control circuit of Claim 11, wherein said sampling circuit comprises a hold circuit having an input coupled to said second winding and an output coupled to an error amplifier for comparing a held voltage of said second winding to a reference voltage, and wherein said compensation circuit comprises a feedback circuit including a chopper coupled between said second winding and an output of said error amplifier, and wherein a control input of said chopper is coupled to said switching control circuit for scaling a voltage of said second winding in proportion to one minus the duty ratio of the switching circuit.

14. A control circuit for controlling a switching power converter, wherein said switching power converter includes a power magnetic element having at least one power winding and a second winding, a switching circuit for periodically energizing
5 said at least one power winding, wherein said control circuit controls said switching circuit, said wherein said control circuit comprises:

a first detection circuit having an input coupled to said second winding for detecting a zero magnetic energy storage
10 cycle point of a post-conduction resonance condition of said power magnetic element;

a second detection circuit coupled to an output of said first detection circuit for detecting a beginning of a subsequent post-conduction resonance condition of said power
15 magnetic element in conformity with an output of said first detection circuit that indicates said detected zero magnetic energy storage cycle point;

a sampling circuit having a control input coupled to said second detection circuit for sampling a voltage of said second winding at a time preceding or equal to said beginning of said subsequent post-conduction resonance condition; and
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a switch control circuit having an output coupled to said switching circuit and having an input coupled to an output of

said sampling circuit, whereby said switching circuit is controlled in conformity with said sampled voltage.

15. The control circuit of Claim 14, wherein said first
5 detection circuit comprises:

a differentiator for providing an output corresponding to a derivative of said voltage of said second winding; and

10 a comparator for determining a time at which said derivative is substantially equal to zero, corresponding to said zero magnetic energy storage cycle point.

16. The control circuit of Claim 15, wherein said comparator is biased with an offset voltage and includes hysteresis, whereby false tripping of said differentiator is prevented.

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17. The control circuit of Claim 16, wherein an output of said first detection circuit is coupled to said switch control circuit for activating said switching circuit at said zero magnetic energy storage cycle point, whereby efficiency of said
20 power converter is improved.

18. A method of controlling a switching power converter,
comprising:

periodically energizing a power magnetic storage element;

sensing magnetic flux in said power magnetic storage

5 element via a second winding;

integrating a first voltage across said second winding to
determine a second voltage corresponding to a level of magnetic
energy storage in said power magnetic storage element;

comparing said second voltage to a threshold to determine a
10 sampling time at which said level of magnetic energy storage is
substantially equal to zero;

sampling said first voltage at said sampling time; and

controlling subsequent energizing of said magnetic storage
element in conformity with said sampled first voltage.

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19. The method of Claim 18, further comprising:

first detecting a zero magnetic energy storage cycle point of a post-conduction resonance condition of said power magnetic storage element in conformity with said sensed magnetic flux;

5 second detecting a beginning of a subsequent post-conduction resonance condition of said power magnetic element in conformity with an indication of said detected zero magnetic energy storage cycle point and a result of said integrating; and determining said sampling time preceding or equal to said 10 beginning of said subsequent post-conduction resonance condition in conformity with said indication of said zero magnetic energy storage cycle point and further in conformity with a result of said integrating.

15 20. The method of Claim 19, wherein said first detecting comprises:

differentiating said first voltage; and

20 second determining when said derivative is substantially equal to zero, corresponding to said zero magnetic energy storage cycle point.

21. The method of Claim 20, further comprising enabling said first detecting only during post-conduction resonance intervals.

22. The method of Claim 19, further comprising initiating said energizing in response to said first detecting, wherein said energizing is commenced at said zero magnetic energy storage cycle point, whereby efficiency of said power converter is
5 improved.

23. The method of Claim 18, further comprising deactivating said switching circuit in response to a result of said integrating indicating that a level of magnetization current is reached in
10 said power magnetic element corresponding to a difference between a voltage of said second winding at said sampling time and a reference voltage, whereby a peak current of said switching circuit is regulated.

24. A method of controlling a switching power converter,
comprising:

periodically energizing a magnetic storage element;

sensing magnetic flux in said magnetic storage element via

5 a second winding;

first detecting a zero magnetic energy storage cycle point
of a post-conduction resonance condition of said power magnetic
storage element in conformity with said sensed magnetic flux;

second detecting a beginning of a subsequent post-

10 conduction resonance condition of said power magnetic element in
conformity with a result of said first detecting;

sampling a voltage of said second winding at a time
preceding or equal to said beginning of said subsequent post-
conduction resonance condition; and

15 controlling subsequent energizing of said magnetic storage
element in conformity with said sampled voltage.

25. The method of Claim 24, wherein said first detecting
comprises:

20 differentiating said first voltage; and

second determining when said derivative is substantially
equal to zero, corresponding to said zero magnetic energy
storage cycle point.

26. The method of Claim 25 further comprising enabling said first detecting only during post-conduction resonance intervals.

27. The method of Claim 24, further comprising initiating said
5 energizing in response to said first detecting, wherein said energizing is commenced at said zero magnetic energy storage cycle point, whereby efficiency of said power converter is improved.

28. A switching power converter comprising:

a power magnetic element having at least one power winding
and a second winding;

a switching circuit for periodically energizing said at

5 least one power winding; and

a control circuit, comprising:

an integrator having an input coupled to said second
winding for providing an output representing an amount of
magnetic energy storage in said power magnetic element,

10 a comparison circuit for detecting when said output of
said integrator indicates that said amount of magnetic
energy storage has reached a level substantially equal to
zero,

15 a sampling circuit having a signal input coupled to
said second winding and a control input coupled to an
output of said comparison circuit for sampling a voltage of
said second winding in conformity with said integrator
indicating that said amount of magnetic energy storage has
reached said substantially zero level, and

20 a switch control circuit having an output coupled to
said switching circuit and having an input coupled to an
output of said sampling circuit, whereby said switching
circuit is controlled in conformity with said sampled
voltage.

29. The switching power converter of Claim 28, further comprising:

an energy storage capacitor coupled to said switching circuit for maintaining a substantially DC voltage at an 5 internal node of said switching power converter for periodically energizing said power magnetic element therefrom;

an input inductor coupled to an input of said switching power converter and further coupled to said switching circuit for shaping an input current of said switching power converter 10 to maintain said input current proportional to an instantaneous voltage of said switching power converter input, wherein said input inductor transfers all stored energy to said energy storage capacitor during each switching period of said switching circuit, and wherein said switch control circuit controls all 15 switches of said switching circuit so that charging of said energy storage capacitor and charging of said power magnetic element are performed alternatively under common control.

30. The switching power converter of Claim 28, wherein said 20 power magnetic element is an inductor including said second winding and coupled to an output of said switching power converter.

31. The switching power converter of Claim 30, further comprising a second power magnetic element having a secondary winding coupled in series with said inductor, wherein a primary winding of said second power magnetic element is coupled to said
5 switch, and wherein said inductor is periodically energized by said switch via said second power magnetic element.